

EXTERNALITIES AND THE PLACEMENT OF
PROPERTY RIGHTS: AN ALTERNATIVE
FORMULATION TO THE STANDARD PIGOUVIAN RESULTS

by

Raymond S. Hartman

Working Paper MIT-EL 77-032WP

October 1977

TABLE OF CONTENTS

1.0	INTRODUCTION	1
2.0	THE TRADITIONAL WELFARE RESULTS	5
3.0	AN ALTERNATIVE FORMULATION	9
4.0	INSIGHTS FOR PUBLIC POLICY	23
	BIBLIOGRAPHY	28

1.0 INTRODUCTION

Much of the traditional and contemporary welfare literature dealing with externalities supports the Pigouvian tradition that taxes upon the generator of the externality are all that are required for obtaining optimal resource allocation (1). While Buchanan (5) and Davis and Whinston (10) have questioned this assertion in situations of monopoly and oligopoly, for the case of a large number of participants (consumers and producers) the Pigouvian results are widely accepted.

At the same time, there has been a growing literature examining externalities within the interface of law and economics. This literature has aimed at assessing the effects of legal institutions both upon very specific economic phenomena and upon the general way economists think. Examples of the former include analysis of the effects of products' safety and liability law (17, 18, 20) and accident liability law (4, 7). Examples of the latter include historical/philosophical examinations of the evolution of property rights (12, 13) and philosophical discussions of the interrelationships of property rights and externalities (8, 13). Perhaps the most prominent example is the Coase discussion (8) of social cost.

While the traditional Pigouvian welfare literature accepts legal institutions (such as property rights) as given, the literature dealing with the interface of law and economics examines the role of changing legal institutions. For example, Pigouvian discussions of the traditional smoke externality always assume that property rights are such that air is a free good; the fact that there exist no property rights (or liability for polluting) for clean air generates the externality.

However, "a primary function of property rights is that of guiding incentives to achieve greater internalization of externalities. Every cost and benefit associated with social interdependencies is a potential externality."¹ They remain externalities if the cost of the transaction of rights exceeds the gains from internalization of the externality. In the case of pollution externalities, the United States has clearly felt over the past ten to fifteen years that the gains from the internalization of the externalities exceed the costs of transaction, hence the wide array of pollution-abatement legislation and judicial decisions. The literature on the interface of law and economics examines alternative forms of internalization by taking account of the fact that changes in knowledge result in changes in production functions, market values, and consumer/producer aspirations. New techniques, new products, and new values all invoke harmful and beneficial effects to which society is unaccustomed. The emergence of property rights² takes place in response to the desires of the interacting persons to internalize new externalities in light of new benefit/cost possibilities and comparisons.

The principles represented by these two areas of literature have been found to be both conflicting and harmonious. Coase claims that the Pigouvian treatment of the divergence of the social and private product of a factory belching smoke (the usual externality example) has led to proposals that the factory be liable for smoke damage, or that a tax be

¹See (12) and (13).

²See (13) p. 348.

placed upon the factory varying with the amount of smoke (and equivalent to the damage caused) or that the factory be excluded from residential districts or industrial districts where the smoke can cause production externalities. He furthermore states that, "it is my contention that these suggested courses of action are inappropriate, in that they lead to results which are not necessarily, or even usually, desirable."¹

Baumol, on the other hand, defends the Pigouvian tradition and claims "that the issue Coase himself intended to raise was rather more subtle and his conclusions are not necessarily at variance with the Pigouvian prescription."²

Taking the major insight of Coase's discussion to be that every externality is essentially reciprocal in nature,³ it is my contention that the Pigouvian tradition does indeed lead to socially unoptimal policy prescriptions. It is my further contention that by properly incorporating Coase's insights, the optimal social solution can be obtained. In order to demonstrate these contentions, I develop a simple model of the Pigouvian prescriptions in Section 2.0 below. For expositional ease and notational continuity I borrow Baumol's formulation entirely⁴ for the development. In Section 3.0, I develop an

¹Coase (8), pp. 1-2.

²Baumol (1), p. 309.

³His confectioner versus the doctor example. Baumol does call this concept "Coase's central argument." (1), p. 309.

⁴In (1). This formulation is also the basis for (16).

alternative interpretation of the Coase argument in light of the literature dealing with the placement of property rights and liabilities. I shall argue that the original insight of Coase is that liability rules and property rights in our legal system have tended to make economists view externalities in an all-or-nothing context; either a factory has no liability for the soot it belches (the externality exists) or the factory is fully liable and the proper Pigouvian effluent fees are levied. Furthermore, this all-or-nothing view does ignore the reciprocal nature of externalities.¹ I contend that when both (several) parties of an externality can take measures to effectively reduce or eliminate the externality, the standard theory of production with two (several) inputs and one output will yield conditions for a socially optimal amount of "externality elimination." I shall demonstrate in Section 3.0 that given the usual convexity assumptions, the minimum social cost elimination of an externality (factory smoke or the mutual encroachment of Coase's doctor and confectioner) may require costs to be borne by both parties of an externality (the polluter and the pollutee; the doctor and the confectioner of Coase).

Finally, section 4.0 relates the insights of Sections 2.0 and 3.0 to specific current public policy action directed at externalities.

¹This reciprocity is discussed below and in (4) and (8).

²It does take two to tango and the dance fee should be borne by both partners. (See (2)).

2.0 THE TRADITIONAL WELFARE RESULTS

To demonstrate that "the conclusions of the Pigouvian tradition are, in fact, impeccable...Pigouvian taxes upon the generator of the externality are all that is required,"¹ Baumol constructs an elementary general equilibrium model designed to represent the Coase arguments, but departing from it only by an assumption of universal perfect competition. He assumes that there is only one scarce resource, labor, and that the externality (smoke) only affects the cost of production of neighboring laundries, rather than causing disutility for consumers.² He utilizes the following notation:

Let

$X_1, X_2, X_3,$ and X_4 be the outputs of the economy's four activities, I, II, III, and IV;

R be the total supply of the labor resource available;

X_5 be the unused quantity of labor (which is assumed to be utilized as leisure);

X_{ij} be the quantity of X_i consumed by individual j ($i = 1, \dots, 5$), ($j = 1, \dots, m$);

$P_1, P_2, P_3, P_4,$ and p_5 be the prices of the four outputs and leisure;

$u_j(X_{1j}, \dots, X_{5j})$ be the utility function of individual j ;
and

¹(1), p. 307. This section quotes liberally from pp. 309-311.

²It is easy to show that neither of these simplifications, nor the assumption that there are only four activities, affect the substance of the discussion.

$C_1(X_1)$, $C_2(X_1, X_2)$, $C_3(X_3)$, and $C_4(X_4)$ be the respective total labor cost functions for the four outputs.

In the model, the production of output X_1 imposes external costs upon the production of X_2 . Baumol uses the traditional example that the smoke from X_1 affects the laundry production, X_2 . For the discussion here, X_3 and X_4 can be thought of as entirely different products. Baumol treats X_3 and X_4 as perfect substitutes for X_1 and X_2 except that X_3 and X_4 are considered to experience no externalities (X_3 is equipped with pollution abatement equipment and X_4 has been relocated to avoid the smoke of X_1). He claims such a specification permits the full range of Coase's alternative. This is not true as indicated in Section 3.0; even if it were true, it is irrelevant to Baumol's derivation of the Pigouvian prescription.

Treating labor as the numeraire ($p_5 = 1$), Pareto optimality requires maximization of the utility of any arbitrarily chosen individual, say m , subject to the requirement that there be no loss in utility to any of the $m - 1$ other persons, i.e., given any feasible level for these other persons' utility. Thus the problem is to maximize

$$u_m(X_{1m}, \dots, X_{5m})$$

subject to

$$u_j(X_{1j}, \dots, X_{5j}) = k_j \text{ (constant), } (j = 1, 2, \dots, m - 1)$$

$$\sum_{j=1}^m X_{ij} = X_i \text{ (} i = 1, \dots, 5 \text{)}$$

¹(1), p. 310.

and the labor requirement (production function) constraint

$$C_1(X_1) + C_2(X_1, X_2) + C_3(X_3) + C_4(X_4) + X_5 = R.$$

Forming the Lagrangian, we have

$$\begin{aligned} L = & \sum_{j=1}^m \lambda_j [u_j(X_{1j}, \dots, X_{5j}) - k_j] \\ & + \sum_i v_i (X_i - \sum_j X_{ij}) \quad (1) \\ & + \mu [R - C_1(X_1) - C_2(X_1, X_2) \\ & - C_3(X_3) - C_4(X_4) - X_5]. \end{aligned}$$

Then, differentiating in turn with respect to the X_{ij} and the X_i we obtain the first-order conditions

$$\begin{aligned} \partial L / \partial X_{ij} = \lambda_j u_{ji} - v_i = 0 \quad (i = 1, \dots, 5) \quad (2a) \\ (j = 1, \dots, m) \end{aligned}$$

$$\partial L / \partial X_i = -\mu (C_{11} + C_{21}) + v_i = 0 \quad (2b)$$

$$\partial L / \partial X_i = -\mu C_{ii} + v_i = 0 \quad (i = 2, 3, 4) \quad (2c)$$

$$\partial L / \partial X_5 = -\mu + v_5 = 0 \quad (2d)$$

where u_{ji} represents $\partial u / \partial x_{ij}$ and C_{ik} represents $\partial C_i / \partial x_k$ (or dC_i / dx_k , where appropriate).

¹where $\lambda_m = 1$ and $k_m = 0$.

For consumer equilibrium for any commodities a and b, $u_{ja}/u_{jb} = P_a/P_b$ ($j = 1, \dots, m$) and $W_j P_i = u_{ji}$ for all i and some W_j . Multiplying by λ_j we obtain $\lambda_j W_j P_i = \lambda_j u_{ji} = v_i$ for all i and j by equation (2a). If $\lambda_j W_j P_i = v_i$ for all j, then $\lambda_j W_j = \kappa$ and $\kappa P_i = v_i$. As a result equations (2b) - (2d) become

$$\mu(C_{11} + C_{21}) = \kappa P_1$$

$$\mu C_{ii} = \kappa P_i \quad (i = 2, \dots, 4)$$

$$\mu = \kappa P_5 = \kappa \quad (\text{since } P_5 = 1)$$

Dividing the first four equations by $\mu = \kappa$, Baumol obtains the standard Pigouvian results:

$$\begin{aligned} C_{11} + C_{21} &= P_1 \\ C_{ii} &= P_i \quad i = 2, \dots, 4 \\ P_5 &= 1 \end{aligned} \quad (3)$$

The optimal price is equal to marginal private cost where social and private marginal costs are identical (i.e., $i = 2$ through 4). For the externality generating output X_1 , the optimal price internalizes the externality (C_{21}) making P_1 equal to the full social marginal cost.

Thus, in Baumol's construction, to obtain the socially optimal prices in free competition, "one need merely levy an excise tax on item I equal to C_{21} (labor hours) dollars per unit, just as the Pigouvian tradition requires, "... the solution calls for neither taxes upon X_2 , the neighboring laundry output nor compensation to that industry for the damage it suffers." (Emphasis is Baumol's and mine).¹

¹(1), p. 311.

3.0 AN ALTERNATIVE FORMULATION

The second analytic area of the literature mentioned in the introduction focuses upon the interface of law and economics. The topics most often discussed within this literature include the placement of liability and property rights. The interest of this paper includes externalities, their interpretation within the context of property right placement and the relationship of this interpretation to the traditional Pigouvian welfare results. However, in order to develop the analytic constructs relevant to address the discussion of Section 2.0, it is useful to first deal with the literature's analysis of liability placement and the concept of the "least-cost avoider" (LCA). This discussion is then extended to the situation of externalities, particularly to the pollution externality example used in Section 2.0. Based upon this development, the difficulties with the usual Pigouvian treatment (as articulated through Baumol's mathematics) are indicated. Finally, an alternative formulation is offered within the framework of the Baumol model.

To begin the discussion, it is necessary to indicate the meaning of the LCA concept within the context of liability placement. Quite simply the least cost avoider concepts states that in situations where liability is to be assigned, it is socially optimal to place liability upon the party who shall expend the least cost to avoid a particular undesirable action or event. This formulation has important implicit judgments. It assumes that responsibility (liability) for an accident or undesirable event involving two parties does not rest with the person who "caused"

the accident or event. Rather, both parties are assumed to "cause" the accident or undesirable event. For example, if an auto strikes a pedestrian, neither the driver nor the pedestrian alone caused the accident; both parties exercising relative levels of care and/or negligence caused the accident. Likewise, in the pollution example of Section 2.0, neither the smoke-belching factory nor the laundry "caused" the externality alone; the combination of the two in proximity generate the externality.¹ This reciprocity of accident or externality causation is precisely the insight in Coase's work.²

Since both parties are assumed to cause the accident, the LCA concept attempts to obtain socially optimal levels of accident avoidance by placing liability upon the party that can avoid an accident at least cost. As a result, liability is an all-or-nothing formulation;³ whichever participant can avoid an undesirable effect at least cost bears full responsibility (liability) to do so -- even if the several parties combined could avoid the undesirable effect at lower social cost.

The least cost avoider (LCA) concept is well defended in the literature. Brown⁴ cites support for the LCA concept by Calabresi. Demsetz⁵ claims that "it is difficult to suggest any criterion for

¹As Brown states (4), attempts to place full responsibility for an accident or externality upon one party alone is analogous to the nineteenth century debates about whether labor or capital caused production. Both are needed.

²(8).

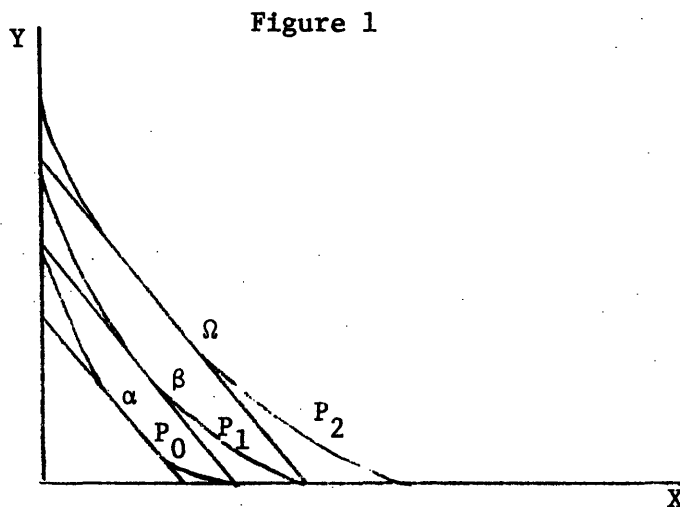
³Brown examines more complicated liability formulations. See (4).

⁴Brown (4), p. 326.

⁵Harold Demsetz, "When Does the Rule of Liability Matter?," Journal of Legal Studies, 13 (1972).

deciding liability other than placing it on the party able to avoid the costly interaction most easily." McKean explicitly and implicitly supports the LCA concept.¹

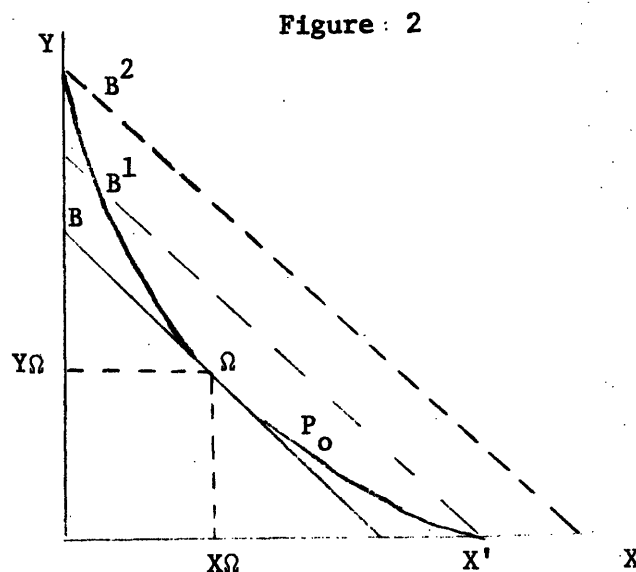
However, only under very restrictive conditions can one usefully apply the all-or-nothing LCA concept in analyzing liability placement. This can be illustrated utilizing the analytic tools of Brown² as given in Figure 1. Figure 1 also conceives of accident avoidance in a production sense. The isoprobability lines $P_i(X,Y)$ reflect the probability of avoiding an accident given inputs of "care" by persons X and Y. If each $P_i(X, Y)$ is multiplied by the cost of the accident, A, then the $A \cdot P_i(X, Y)$ production map indicates the expected levels of "accident avoidance" produced in inputs of "care," X and Y. The social optimum for any $P_i(X, Y)$ or $A \cdot P_i(X,Y)$ is the least cost solution to obtaining a level of accident avoidance -- given by the tangency with the budget lines (at α , β , and Ω). W_x and W_y are Brown's unit costs of care for X and Y and determine the slope of the budget lines.



¹McKean (17).

²Brown (4).

Figure 2 recreates a single isoprobability curve. In Figure 2 it can be seen that the use of the LCA concept in order to apply either strict or no liability will lead to social inefficiency. Brown shows in his discussion that the imposition of either strict liability or no liability will divert the equilibrium production of accident avoidance from the social optimal levels of care. In Figure 2, Ω is the least-cost solution (X_{Ω}, Y_{Ω}) for the production of P_0 . Given the convex "accident avoidance" technology, the imposition of liability upon a single party shall lead to inefficiency even if that party is the "least cost avoider." In Figure 2, if the LCA concept is used, full liability will be placed upon X, since $B^1 \leq B^2$. However, the social cost, B^1 , is clearly greater than B, and $(X^1, 0)$ is clearly socially inferior to (X_{Ω}, Y_{Ω}) .



However, the concept of the "least cost avoider" will not always be inefficient when assessing strict liability or no liability. Figure 1 can be altered to indicate when the LCA concept will generate the social optimum. The case would arise when the technology of accident avoidance and the unit costs of "care" to X and Y were such that a corner solution were obtained. Such a case is presented in Figure 3, where

$$\frac{W_x}{W_y} > \frac{P_x(X,Y)}{P_y(X,Y)} \quad (4)$$

The usual Kuhn-Tucker conditions hold in this case and $X = 0$.¹ If we transpose equation (4), we obtain

1 The problem is to $\text{MAX } P(X,Y)$, s.t. $W_x X + W_y Y \leq B$. We obtain

$$L(X,Y) = P(X,Y) + \lambda(B - W_x X - W_y Y).$$

The first order conditions yield

$$\begin{aligned} P_x - \lambda W_x &\leq 0 \\ X(P_x - \lambda W_x) &= 0 \\ P_y - \lambda W_y &\leq 0 \\ Y(P_y - \lambda W_y) &= 0 \end{aligned}$$

When $X = 0$, we have

$$\begin{aligned} P_x &< \lambda W_x \\ P_y &= \lambda W_y \end{aligned}$$

Dividing through, we obtain the equation in the text.

$$\frac{P_y(X,Y)}{W_y} > \frac{P_x(X,Y)}{W_x} \quad (5)$$

which implies that the relative amount of accident avoidance purchased per dollar spent by Y is greater than that of X for all values of X and Y along an isoprobability line. In other words, Y does indeed have a comparative advantage in providing accident prevention. In this case, Y is the "least cost avoider" for all possible combinations of X and Y and should inherit the liability.

The technology of a particular accident and its prevention and the relative unit costs of "care" may be such that the inequality of equation (5) is reversed. Under those circumstances, X will be the "least cost avoider" for all combinations of care levels along each isoprobability line. The social optimum will be obtained by placing full liability upon X, since he can purchase more "accident avoidance" per dollar than can Y. See Figure 4.

In these two examples, the "least cost avoider" has a comparative advantage in preventing an accident because the cost of a unit of "accident avoidance" is always cheaper for that person. In these cases, the all-or-nothing rules of either "no liability or "strict liability" will be efficient. Returning to Figure 1, however, we find that neither person X nor Y has sole comparative advantage over all levels of X and Y along $P_i(X,Y)$. Certainly along portions of the isoprobability curves

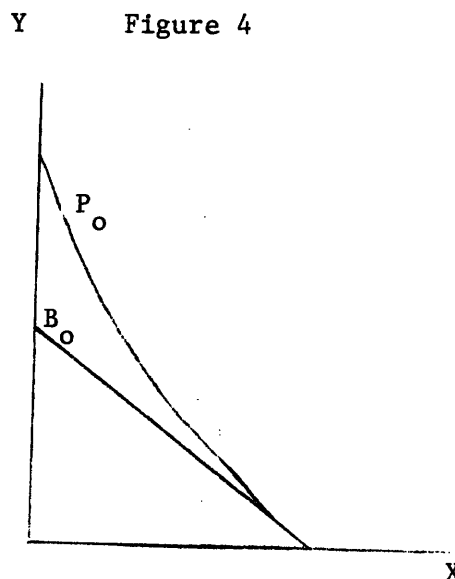
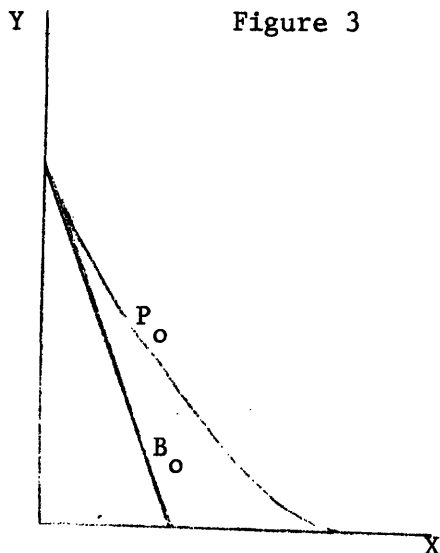
both X and Y will possess a comparative advantage at different levels of care. Yet both persons experience decreasing returns to a unit of "care" and ultimately the point is obtained where

$$\frac{W_x}{W_y} = \frac{P_x(X,Y)}{P_y(X,Y)} ; \frac{P_x(X,Y)}{W_x} = \frac{P_y(X,Y)}{W_y} \quad (6)$$

Neither person has sole comparative advantage to "care" and both parties should be required to expend resources until the last unit of accident avoidance per dollar is the same for both.

The extension of these concepts to the placement of property rights for particular externalities is immediate. Using Figures 1-4, assume that rather than liability placement and accident avoidance, we are interested in externality elimination (when the externality is bad) and responsibility for that elimination. Assume further that the externality is the smoke generated by output X_1 in Section 2.0 above. In the diagrams, let X_1 be X, and X_2 be Y (the laundry in Baumol's example). In Figure 1, let P_0 , P_1 , and P_2 be isoquants of externality or pollution elimination.¹ Just how the technology is characterized depends upon the given externality and the participants (see Section 4.0). In the Baumol example, inputs by either industry I or II can eliminate the externality or the disagreeable aspects of the smoke. Furthermore, joint inputs by both I and II will eliminate a certain amount of externality.

¹For example, they could be assumed to reflect abatement standards in terms of amount of pollutant per cubic meter of air. See Section 4.0.



Using Figure 2, it becomes clear that from a production point of view that the effective elimination of an externality (bad) is optimally performed using inputs of elimination of both X and Y (with unit costs of W_x and W_y) given the assumed convexity of pollution elimination and the relative costs of elimination. As with liability placement, all-or-nothing property rights in Figure 2 are suboptimal. Strict polluter liability (industry I or X bears full responsibility at budget line B_1) or no pollution liability (industry II or Y bears full responsibility at budget line B^2) generates socially suboptimal solutions when the actual optimal solution is Ω , utilizing levels of externality elimination X_Ω and Y_Ω . As with liability placement, the concept of the least cost avoider is inappropriate unless the externality elimination technology is such as characterized in Figures 3 and 4.

In this context it should be clear that Coase's own discussion¹ and Baumol's interpretations seem to miss the crucial point of Coase's "The Problem of Social Cost." That point is again the inherent reciprocity of externalities and the mutuality of their elimination. As with accident liability (or factors of production) neither the polluter nor the pollutee generate the externality; they both do, and as is seen in Figure 2, some mixed responsibility (X_Ω , Y_Ω) for elimination of the externality may be optimal.

Baumol's and Coase's discussions treat externality elimination as a single factor production activity. Coase's examples generally stress that the least cost avoider eliminate the externality by some action. Baumol deals with the fact that either the polluter or pollutee can eliminate the externality claiming that there exists "a multiplicity of local maxima."³ However, the existence of the "multiplicity of local maxima" is possible only with all-or-nothing property rights -- strict polluter liability or no pollution liability. In this case, we are back in the world of the least cost avoider, which is optimal only in a world characterized by externality elimination costs and technologies shown in Figures 3 and 4. In a world characterized by Figures 1 and 2, there does not exist Baumol's multiplicity of local maxima, only global maxima (α , β , Ω). Coase's and Baumol's arguments for the least cost avoider to bear the responsibility for eliminating the externality lead to suboptimal results. Shared efforts at externality elimination are optimal.

¹(8).

²(1).

³(1), pp. 313 -314.

Given these developments, let us return to Baumol's model and the Pigouvian derivation of Section 2.0. It will be recalled that within his general equilibrium model, Baumol's X_1 is the output which imposes the externality upon the production of X_2 . The model does not stop here; two other industries are introduced, each producing perfect substitutes for X_1 and X_2 . But in a very important sense, the model does stop with Baumol's definition of X_1 , X_2 , and their technological interaction. The remaining maximization under constraints generates the usual Lagrangian solutions. However, by specifying the externality of X_1 upon X_2 as $C_2(X_1, X_2)$ Baumol cannot fail to obtain his desired result:

$$\begin{aligned} P_1 &= C_{11} + C_{21} & (3) \\ P_i &= C_{ii} \quad \text{for } i = 2, \dots, 4 \end{aligned}$$

That is, the price of the externality generating product equals its entire social marginal cost while the prices of all other products are equal to their private marginal costs.

In this formulation, the pollution externality is expressed technologically and legally as $C_2(X_1, X_2)$. This is the natural legal formulation because, for hundreds of years, air has been treated as a free good and responses to the externality (divergence of social and private marginal costs due to a lack of markets) have been of the form $C_2(X_1, X_2)$ -- strict pollutee liability. However, by altering the

legal aspects of the externality we could obtain strict polluter liability so that the cost functions of industries I and II become $C_1(X_1, X_2)$ and $C_2(X_2)$. In this case, the "Pigouvian" results become

$$P_1 = C_{11} \quad (6)$$

$$P_2 = C_{22} + C_{12}$$

$$P_i = C_{ii} \quad i = 3 \text{ and } 4$$

and prices for industry II bear the full social marginal cost, while prices for all other products bear their private marginal costs.

The fact that the results in equation (6) suggest that the industry which is traditionally considered to suffer from the effects of the smoke externality bear the full social cost of that smoke, indicates that the Pigouvian results rest entirely upon how the externality, its cost, and the assignment of property rights are treated. Suppose we interpret Coase's insight that an externality is a reciprocal imposition and view "production of its elimination" as a production activity.¹

¹ Actually one may think of the usual Pigouvian solution as involving a production activity for externality elimination. Assume the Pigouvian tax is levied upon the factory and the tax can be totally passed on. The factory is then producing two goods -- X_1 and clean air, if the externality is soot. However, it is not clear that the factory can eliminate the effects of the externality at the lowest social cost.

In Baumol's model, in that case, we would have an entirely new production activity, X_E , the elimination of the pollution externality where industries I and II were responsible for the activity. Its cost function would be $C_E(X_1, X_2)$. In this case, the Lagrangian would become

$$\begin{aligned}
 L = & \sum_{j=1}^m \lambda_j [u_j(X_{1j}, \dots, X_{5j}) - k_j] \\
 & + \sum_i v_i (X_i - \sum_j X_{ij}) \\
 & + \mu [R - C_1(X_1) - C_2(X_2) \\
 & \quad - C_3(X_3) - C_4(X_4) \\
 & \quad - C_E(X_1, X_2) - X_5]
 \end{aligned}$$

and

$$\begin{aligned}
 P_1 &= C_{11} + C_{E1} \\
 P_2 &= C_{22} + C_{E2} \\
 P_3 &= C_{33} \\
 P_4 &= C_{44} \\
 P_5 &= 1
 \end{aligned} \tag{7}$$

where part of the social cost appears in the prices of both activities 1 and 2. Thus, depending upon how one defines the internalization of the externality, different results obtain. The optimality results of equation (7) are different from Baumol's (3) and from (6).

Equation sets (3), (6), and (7) all result in social optima, given the assignment of property rights and the definition of externality. If the Pigouvian tradition is interpreted to be results (3) (as Baumol interprets), then it is clear that alternative results are possible given different definitions of the problem. However, there should be methods of choosing between results (3), (6), and (7). If the concern is utilizing the Pigouvian solution (3) or the alternatives to eliminate the externality at the lowest social cost, then Figures 1-4 will help indicate which solution is optimal as follows.

Accepting the insight that a given externality is mutually and reciprocally imposed, then the levels of "effective elimination" of the effects of that externality can be produced jointly by both (industries) X and Y. The isoquants (in Figures 1-4) then represent the resources expended by industries I and II (remember X is industry I and Y is industry II) to obtain a given level of "effective elimination" of the effects of an externality. The usual convexity assumptions are assumed to hold for the technology of "effective externality elimination:" the greater the resources substituted by X for those of Y, the less effective they will be.

Because we are examining the "effective elimination" of the effects of pollution as a production process, inputs of both X and Y can be used. If Y has a comparative advantage in eliminating the effects of pollution for all X and Y along a given isoquant in Figure 3, then strict pollutee liability would be efficient since

$$\frac{P_y(X,Y)}{W_y} > \frac{P_x(X,Y)}{W_x} \quad \text{all } X \text{ and } Y$$

where W_y and W_x are the unit costs of inputs of X and Y. In this case, the technology of pollution elimination always favors abatement activities by Factory II (X_2).¹ In Figure 4, Factory I (X_1) has the comparative advantage. It can install stack gas scrubbers, etc., to effectively eliminate pollution's adverse effects at the lowest social cost (or move away).

However, I would venture that within this simple model a situation will obtain such as in Figure 2, where the social optimum requires that resources be expended by both industries to obtain the social least-cost solution. In that case, both factories should further abatement until the last dollar spent by each purchases an equal level of "effective elimination." Shared responsibility and shared abatement efforts will be optimal. Factory I may be required at (X_Ω , Y_Ω) to install stack gas scrubbers to eliminate a certain amount of pollution. However, beyond a certain point, the marginal benefits of abatement efforts may be socially more costly if accomplished through additional scrubbers rather than through incremental efforts by Factory II (the laundry) to eliminate the effects of the pollution (say through fences, wind directional machines, and intake-air purifiers).²

¹ It could move away, in Coase's examples.

² This discussion leaves out a number of important details such as a precise definition of "effective elimination," and a closer questioning of the constancy of W_x and W_y , to name a few. However, I think it indicates the possible insights gained by thinking about externalities in terms of Coase's reciprocity.

Thus given convexity assumptions it is probable that shared externality elimination is optimal. Since the traditional Pigouvian results (3) impose externality elimination upon the polluter they cannot be optimal except if the situation is as found in Figure 4.

4.0 INSIGHTS FOR PUBLIC POLICY

The Pigouvian principles discussed in Sections 2.0 and 3.0 form the basis for much of the public policy analysis in the academic and nonacademic literature. With a strong proclivity toward Pigouvian principles, Baumol and Oates, for example, examine the use of standards and prices for environmental protection.¹ Furthermore, the Occupational Safety and Health Administration (OSHA), the Environmental Protection Agency (EPA), the Labor Department, and a variety of other federal, regional, and state agencies have articulated proposed policy thrusts utilizing traditional Pigouvian results. Thus the policy recommendations seem to utilize all-or-nothing property right conceptualizations. In light of the results of Section 3.0, it may be appropriate to rethink some of these policy suggestions.

Two examples are discussed here: The first involves proposed EPA abatement legislation for the U.S. copper industry, and the second involves Labor Department/OSHA regulations for lead exposure and emissions from coke ovens. Details of the EPA legislation abatement proposals for the U.S. copper industry are found in an Arthur D. Little report.²

¹ See (3).

² Arthur D. Little Inc., Economic Impact of Environmental Regulations on the U.S. Copper Industry, Report to the EPA (September 1977).

That report traces the history of air and water quality legislation as it affects the U.S. copper industry.¹ The report also treats the controversial issues which arise from the 1970 Clean Air Act Amendments. The controversy concerns SO₂ emissions and the relative desirability of permanent control devices (scrubbers) versus the advantages and legality of intermittent control devices. "Scrubbers remove sulfur from stack gases after combustion but before emission into the atmosphere. Intermittent control systems seek to disperse stack gas and dilute SO_x emissions by the use of tall stacks and various operating practices, including curtailing operations or switching to low-sulfur fuels during times of adverse air quality or other unusual meteorological conditions."²

The capital cost differences between these two forms of control can be considerable. Permanent controls must be able to meet EPA standards every day of the year. Hence, control devices must be efficient enough to meet the SO_x ambient air quality emission standards for the worst meteorological conditions (such as air inversions) that occur, even though such conditions may occur for a very limited number of days (5-10) during a year. Thus permanent control devices really aim at the 5-10 days per year when meteorological conditions make emissions "too dirty." Intermittent control devices involve much less costly equipment and structures and such devices can meet ambient air quality standards for most of the year except those days when the severe meteorological conditions obtain.

¹ Arthur D. Little Inc., Economic Impact of Environmental Regulations on the U.S. Copper Industry, Report to EPA, (September 1977).

² Ibid., Chapter 8.

In 1974 the U.S. Court of Appeals for the Fifth Circuit, in *Natural Resources Defense Council vs EPA*, held that intermittent control systems are acceptable only when all possible permanent control equipment has been installed. All subsequent court decisions have followed this precedent.¹ It is this decision that has had the greatest effect upon the U.S. copper industry. Of all environmental regulations affecting the four stages of copper production (mining, milling, smelting, and refining), it is the differential impact of intermittent and permanent controls that most severely affects the copper industry at the smelting level. In the initial ADL reports,² it was found that the proposed abatement compliance regulations would have severely adverse price, employment, production, and balance-of-payments effects upon the U.S. copper industry. The reason for the severity of the effects lay almost entirely in the requirement that permanent controls (best available control technology -- BACT) must be put into both existing and new plants (modified or grass-roots) rather than intermittent controls or some combination of permanent and intermittent controls. As a result, capital compliance costs for existing smelters would be large and capacity expansion would be effectively halted, because permanent controls without intermittent controls could not meet EPA standards for new sources.

The requirement that permanent controls be the only form utilized by the copper industry is a form of strict pollution liability/Pigouvian results taken to its illogical conclusion. Clearly the imposition of

¹ Arthur D. Little Inc., Economic Impact of Environmental Regulations on the U.S. Copper Industry, Report to the EPA (September 1977).

² Ibid., Chapter 8.

³ ADL, draft report, Ibid. (October 1976).

standards is only a second best form of the traditional Pigouvian results. However, the legal precedents and regulatory thrust of the pollution abatement proposals reflect the all-or-nothing thinking underlying the strict- or no-liability formulations and the traditional Pigouvian specifications. As seen in Section 3.0, if we view the effective elimination of the externality as a social production process, the insistence of full permanent controls will be socially optimal only if the smelters are the least-cost avoiders as indicated in Figures 3 and 4 (in this case, let X be the smelters and Y be the general population). Such a situation is highly unlikely. The capital costs involved with full permanent controls are large for existing smelters and prohibitive for new smelters. The use of intermittent control devices permits the installation of much less costly capital devices, and permits the smelter to close (or operate) on the 3-5 days during the year when an air inversion or other meteorological condition cause the smelter to exceed EPA limits. If the plant were permitted to operate on the 5 days when its stack gas emissions exceed EPA standards, we obtain a shared property rights/externality elimination situation as found in Figures 1 and 2. The small increase in pollution on those limited days compared with the considerable savings in capital costs strongly suggest that intermittent controls may be socially optimal rather than the strict liability/Pigouvian form of full, permanent controls.

The second example concerns OSHA standards and has the same flavor of comparison between permanent and intermittent controls found in the EPA example. The externality is actually internal to steel mills: it

involves coke-oven emissions (benzene-soluble particulates) and their effect upon workers. Labor Department standards aimed at taking effect January 20, 1977 reduced benzene-soluble particulate emissions to .15 milligrams per cubic meter of air from .2 milligrams averaged over an eight-hour workday. The regulations call for employers to offer coke-oven workers regular medical examinations and special respiratory equipment where appropriate. However, as with earlier job safety rules, personal protection gear (such as the respiration equipment) cannot be primary relied on to meet the standards, but must be used only as an interim measure until physical changes are made in the plants.

Clearly full responsibility is again being placed upon the producers to install permanent capital equipment (at an estimated cost of \$240 million per year for the steel industry) rather than use a shared responsibility approach which would include some combination of respirator equipment (which generates the same level of externality elimination) and capital equipment changes within the plant. While exact estimates of the production technology of externality elimination is required, I would contend that the shared responsibility approach à la Figure 2) will generate the socially optimal (least-cost) production of externality elimination (i.e., the move from .2 to .15 milligrams per cubic meter).

BIBLIOGRAPHY

1. Baumol, W.J., "On Taxation and the Control of Externalities," American Economic Review, 1972, pp. 307-322.
2. Baumol, W.J., "It Takes Two to Tango, or Sind 'Separable Externalities' Uberhaupt Moglich," Journal of Political Economy, Vol. 84, No. 2, 1976, pp. 381-387.
3. Baumol, W.J. and W.E. Oates, "The Use of Standards and Pricing for Protection of the Environment," Swedish Journal of Economics, (March 1971) 73, pp. 42-54.
4. Brown, John Prather, "Toward an Economic Theory of Liability," The Journal of Legal Studies, (June 1973), pp. 332-349.
5. Buchanan, J., "External Diseconomies, Corrective Taxes and Market Structure," American Economic Review, (March 1969), 59, pp. 174-177.
6. Buchanan, J. and W.C. Stubblebine, "Externality," Economica, (November 1962), pp. 371-384.
7. Calabresi, G., The Costs of Accidents, (Yale University Press, New Haven) 1970.
8. Coase, R.H., "The Problem of Social Cost," The Journal of Law and Economics, (October 1960), pp. 1-44.
9. Davis, O. and A. Whinston, "On the Distinction between Public and Private Goods," American Economic Association Papers and Proceedings, (May 1967), pp. 360-373.
10. Davis O. and A. Whinston, "Externalities, Welfare and the Theory of Games," Journal of Political Economy, (June 1962), pp. 241-262.
11. Davis, O. and A. Whinston, "On Externalities, Information and the Government-Assisted Invisible Hand," Economica, (August 1966), 33, pp. 303-318.
12. Demsetz, Harold, "The Exchange and Enforcement of Property Rights," The Journal of Law and Economics, (October 1963), pp. 11-26.
13. Demsetz, Harold, "Toward a Theory of Property Rights," American Economic Association Papers and Proceedings, (May 1967), pp. 347-359.

14. Epstein, Richard A., "A Theory of Strict Liability," The Journal of Legal Studies, 1968, pp. 151-221.
15. Kneese, A.V. and B.J. Bower, Managing Water Quality: Economics, Technology and Institutions, (Baltimore, 1968).
16. Marchand, James R. and Keith P. Russell, "Externalities, Liability, Separability and Resource Allocation," American Economic Review, (September 1973), pp. 611-620.
17. McKean, R., "Products Liability: Implications of Some Changing Property Rights," Quarterly Journal of Economics (October 1970).
18. McKean, R., et al., "Symposium on Product Liability," University of Chicago Law Review (Fall 1970).
19. Meade, J. "External Economies and Diseconomies in a Competitive Situation," The Economic Journal, Vol. LXII (1952), pp. 54-67.
20. Oi, Walter, "The Economies of Product Safety," Bell Journal (Spring 1973).
21. Posner, R.A., Economic Analysis of Law, (Little Brown and Co., 1972).
22. Scitovsky, T., "Two Concepts of External Economies," in Agarwala and Singh, The Economies of Underdevelopment (Oxford University Press, 1963), pp. 295-318.